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Design of CAM Shaft using analytical & FEM

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ABSTRACT:

• Camshaft is used in the engine for transfers' motion to inlet & exhaust valve. If Transfer of motion is not proper then the strokes of the engine will not do in proper way. It also effects on performance of engine. To make work of camshaft in precise way, it is require in order designing a good mechanism linkage of camshaft. In four strokes engine one of the most important component is camshaft, such a important part and that over the years subject of extensive research. In this study, Design of Camshaft is done as per power stroke and suction stroke and its model is done in CATIA and Static and Model Analysis is carried in Ansys. By varying Materials like Cast Iron & Nickel chromium molybdenum steel and find out which is best material Suits for design.

INTRODUCTION:

A cam is a rotating or sliding piece in a mechanical linkage used especially in transforming rotary motion into linear motion or vice versa. It is often a part of a rotating wheel (e.g. an eccentric wheel) or shaft (e.g. a cylinder with an irregular shape) that strikes a lever at one or more points on its circular path. The cam can be a simple tooth, as it is used to deliver pulses of power to a steam hammer, for example, an eccentric disc or other shape that produces a smooth reciprocating (back and forth) motion in the follower, which is a lever making contact with the cam. The cam can be seen as a device that translates from circular to reciprocating (or sometimes oscillating) motion. A common example is the camshaft of an automobile, which takes the rotary motion of the engine and translates it into the reciprocating motion necessary to operate the intake and exhaust valves of the cylinders. The opposite operation, translation of reciprocating motion to circular motion, is done by a crank. An example is the crankshaft of a car, which takes the reciprocating motion of the pistons and translates it into the rotary motion necessary to operate the wheels.

Cams can also be viewed as information-storing and transmitting devices. Examples are the cam-drums that direct the notes of a music box or the movements of a screw machine's various tools and chucks. These diagrams relate angular position to the radial displacement experienced at that position. Several key terms are relevant in such a construction of plate cams: base circle, prime circle (with radius equal to the sum of the follower radius and the base circle radius), pitch curve which is the radial curve traced out by applying the radial displacements away from the prime circle across all angles, and the lobe separation angle (LSA - the angle between two adjacent intake and exhaust cam lobes). Displacement diagrams are traditionally presented as graphs with non-negative values. A camshaft is a shaft to which a cam is fastened or of which a cam forms an integral part. A shaft with cam lobes(bumps) which is driven by gears, a belt, or a chain from the crankshaft. The lobes push on the valve lifters to cause the valves to open and close. The camshaft turns at half the speed of the crankshaft.

Types of Camshafts:

There are several different arrangements of camshafts on engines. We'll talk about some of the most common ones. You've probably heard the terminology:
1.Single overhead cam (SOHC)
2.Double overhead cam (DOHC)
3.Pushrod

Types of Cams:

Concentric Cams:

An concentric cam is a disc with its centre of rotation positioned 'off centre'. This means as the cam rotates the flat follower rises and falls at a constant rate. This type of cam is the easiest to make and yet it is one of the most useful. As it rotates it pushes the flat follower upwards and then allows it to drop downwards. The movement is smooth and at a constant speed.

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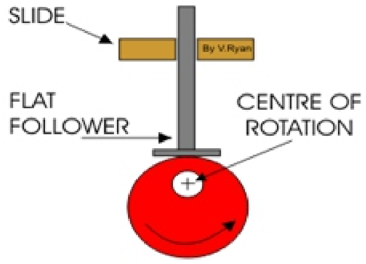


Fig 3.1.1 Concentric cam

1.Droped Cam:

If you dip below the circumference of the circle then the cam follower drops, hence the term drop cam. You can calculate the drop of the cam by measuring from the lowest point of the drop to the circumference. A very popular form of drop cam is called the snail cam. This has a sudden drop that slowly rises to the next drop point. This cam is used a lot in automata and is a blend of both drop and lobe cam.

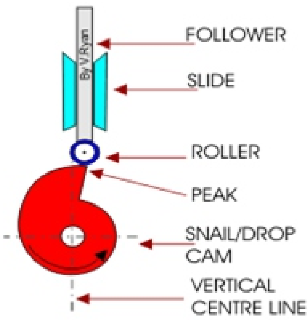


Fig 3.1.2 Droped Cam

2.Offset Cams:

An offset cam not only moves things up and down but also in a circular motion. You must make sure that the cam contacts the cam-follower plate either side of the cam shaft. If it contacts directly underneath then it will only lift. Offsetting two cams either side produces movement in opposite directions, giving you both up and down as well as a side to side movement. Note that the closer the cam is to the center of the follower of the faster and further it will rotate, moving away from the center has the opposite effect.

Cam-follower Plate:

A thin, card cam when used with a wooden dowel cam follower may jam. To avoid this a circular cam-follower known as a Plate should be used. Because of it's large, flat contact area, it is less likely to jam. This type of follower works best with concentric and some lobed cams. It will not work on cams with complicated shapes.

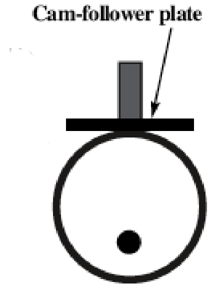
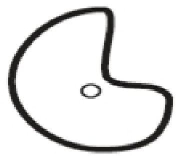


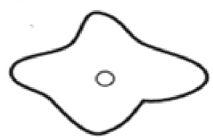
Fig 3.2 Cam Follower Plate

Different Cam Shapes:

1.This cam produces a smooth uplift which suddenly drops down. It is often referred to as a snail cam because of its shape or contour. This cam can only work in one direction. If you turn it the other way the cam-follower would jam. You need to bear this in mind when you are designing cams. To ensure the rotation is smooth, the vertical centre line of the snail/drop cam is positioned slightly to the left of the slide.



2.This cam produces several short up and down movements from one revolution.



3.This cam produces three very distinct movements from one revolution. You can combine as many movements as your cam will allow.

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4.Remember that the cam-follower has to work smoothly. If you try to make it do too much or make the contours too steep, such as this one on the right, it will jam. The cam-followers can only move on gentle curves, make them too tight and you will have problems!

CAM TERMINOLOGY

Angle and Lift Terminology:

There are several terms and abbreviations which are used when discussing camshafts. The following abbreviations have to do with the location of the piston in the cycle.
TC or TDC, Top Center or Top Dead Center (piston at the highest point)
BC or BDC, Bottom Center (piston at lowest point)
BTC or BTDC, Before Top Center (piston rising)
ATC or ATDC, After Top Center (piston lowering)
BBC or BBDC, Before Bottom Center (piston lowering)
ABC or ABDC, After Bottom Center (piston risinng)
Some of the other terms used are illustrated in the drawing and are explained below.

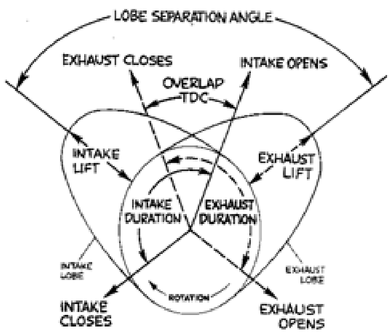

Fig 4.1 Cam Diagram

Valve Opening and Closing Angles, the angles (usually measured in crankshaft degrees) when the valves first leave and then return to their seats. The opening and closing angles may also refer to a specified nominal lift, e.g. at 0.050 in cam lift. For example, a cam's timing may be stated as 25-65-65-25. These numbers are (1) intake opening BTDC, intake closing ABDC, (3) exhaust opening BBDC and (4) exhaust closing ATDC. For these numbers to have meaning, the lift at which the numbers are taken must be specified.

Lobe Terminology:

Some of the terminology, which describes a single lobe is illustrated in the drawing below.

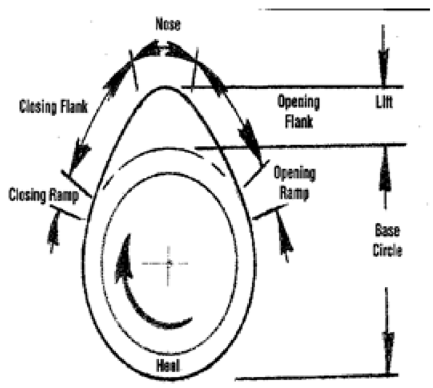

Fig 4.2 Lobe Diagram

Heel or Base Circle, the portion of the cam which is concentric with the bearings and has no lift. Ramps, immediately adjacent to the base circle, the cam has a portion with low velocity so there is not a major collision as slack is removed from the valve train at the start of the lift event. Similarly, a closing ramp is used so the valve will seat gently and not bounce off the seat. Flanks, the portion of the cam with large acceleration and velocity to get the valve moving as quickly as possible Nose or Toe, the portion of the cam with the smallest radius of curvature, opposite the heel. This part has the greatest lift. Asymmetric Lobe, the opening and closing side of the cam are different. Core, the rough part of the camshaft between the lobes, bearings and gears.

4.3 Variable Valve Timing:

There are a couple of novel ways by which car makers vary the valve timing.

1.The variable cam system used on some Ferraris
2.VTEC (Variable Valve Timing and Lift Electronic Control) is an electronic and mechanical system in some Honda engines that allows the engine to have multiple camshafts. VTEC engines have an extra intake cam with its own rocker, which follows this cam. The profile on this cam keeps the intake valve open longer than the other cam profile. At low engine speeds, this rocker is not connected to any valves. At high engine speeds, a piston locks the extra rocker to the two rockers that control the two intake valves.

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3.Some cars use a device that can advance the valve timing. This does not keep the valves open longer; instead, it opens them later and closes them later. This is done by rotating the camshaft ahead a few degrees. If the intake valves normally open at 10 degrees before top dead center (TDC) and close at 190 degrees after TDC, the total duration is 200 degrees. The opening and closing times can be shifted using a mechanism that rotates the cam ahead a little as it spins. So the valve might open at 10 degrees after TDC and close at 210 degrees after TDC.
4.Closing the valve 20 degrees later is good, but it would be better to be able to increase the duration that the intake valve is open.

CAMSHAFT CONFIGURATION
Camshaft configuration:
Single Overhead Cam:

This arrangement denotes an engine with one cam per head. So if it is an inline 4-cylinder or inline 6-cylinder engine, it will have one cam; if it is a V-6 or V-8, it will have two cams (one for each head). The cam actuates rocker arm that presses down the valves, opening them. Springs return the valves to their closed position. These springs have to be very strong because at high engine speeds, the valves are pushed down very quickly, and it is the springs that keep the valves in contact with the rocker arms. If the springs were not strong enough, the valves might come away from the rocker arms and snap back. This is an undesirable situation that would result in extra wear on the cams and rocker arms. On single and double overhead cam engines, the cams are driven by the crankshaft, via either a belt or chain & can be called the timing belt or timing chain. These belts and chains need to be replaced or adjusted at regular intervals. If a timing belt breaks, the cam will stop spinning and the piston could hit the open valves. Damage from a piston striking a valve.

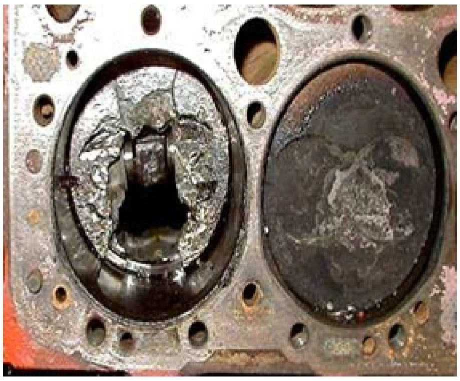

Fig 5.1.1 Damage from a piston striking a valve

The picture above shows what can happen when a piston hits an open valve.

Double Overhead Cam:

A double overhead cam engine has two cams per head. So inline engines have two cams, and V engines have four. Usually, double overhead cams are used on engines with four or more valves per cylinder, a single camshaft simply cannot fit enough cam lobes to actuate all of those valves.

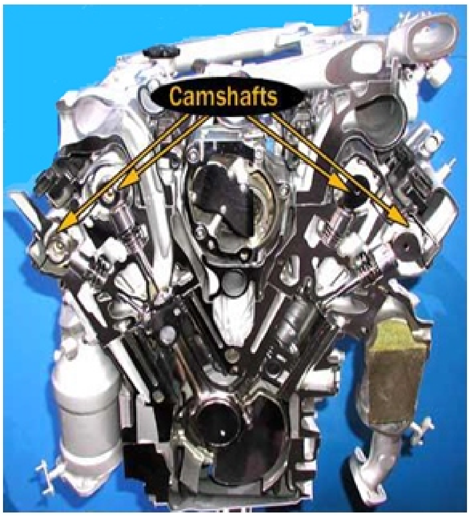

Fig 5.1.2 Double Overhead Cam

The main reason to use double overhead cams is to allow for more intake and exhaust valves. More valves mean that intake and exhaust gases can flow more freely because there are more openings for them to flow through. This increases the power of the engine. The final configuration we'll go into in this article is the pushrod engine.

Pushrod Engine:

Like SOHC and DOHC engines, the valves in a pushrod engine are located in the head, above the cylinder. The key difference is that the camshaft on a pushrod engine is inside the engine block, rather than in the head.

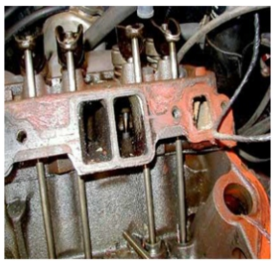

Fig 5.2 A pushrod engine

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Lift Curves:

The purpose of the cam lobe is to raise the lifter and open the valve. You can look at the lobe, but it doesn't tell you exactly how it is going to do its job. The lift curve is a more precise way to look at the cam lift. It is a graph of the lifter (or valve) motion as the cam rotates. Below is an example for a cam with 251 degrees of duration at 0.050 lift. The lift curve can be measured using a degree wheel and dial indicator or more accurately using a computer driven cam profiling system. The opening intake ramp and flank and the intake nose are indicated on the graph. The ramp does not extend much beyond the valve opening, usually less than 0.015 in (0.4 mm) lift. After the ramp, the large upward curvature indicates the start of the flank. The nose portion is the large central area with negative curvature.

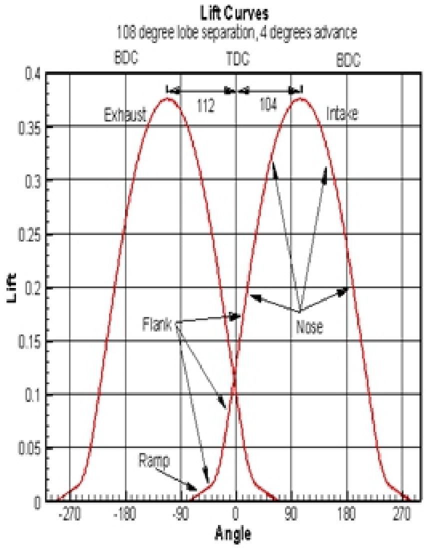

Fig 5.3 Lift Curve

CALCULATIONS

Calculations for camshaft:

Diameter of bore (D¬bore) = 49mm = 0.049 m.
Length of stroke (L) =52mm =0.052m
For continuity equation,
A × V = C
Ac = π/4(Db2),
where Ac = Area of cylinder
= π/4 (0.049)2
= 1.8857 × 10-3 m2
V = 2LN/60
N = Speed of piston
= 2 × 0.052 × 8000/60
= 13.866 m/s
Q = Ac × V = C
Q = 1.8857 × 10-3 × 13.866
= 0.0261 m3/sec

Inlet valve:

Velocity = 85 m/s
π/4 dip2 × Vip = Ac× V
Vip = velocity of inlet port.
π/4 dip2 × 85 = 0.0261
dip = diameter of inlet port.
dip2 = 0.0261 × 4/(π × 85)
= 3.9095 × 10-4
dip = 0.0197 m.
Lift of valve hip = dip/4cosα + 1mm
= 0.01975/ 4cos45 10-3 + 1
[=45]
= 7.9907 × 10-3m.
Exhaust valve:
Velocity = 95 m/s
dep2 ×Vep = Ac ×V
Vep = velocity of exhaust port.
dep2 × 9 = 0.0261
dep2 = 0.0261 × 4/ (95 × π)
= 3.4980 × 10-4
dep2 = 0.0187 m
List of valve = dep/4cosα +1mm
hep = 0.0187/4cos45 + 1×10-3 hip ,
hep = heights of inlet and exhaust ports.
= 6.6114 × 10-3 +1
= 7.6114 × 10-3 m.
Angle of ascent, a = 58˚
Angle of descent, d = 58˚

Design Of Camshaft:

From empirical relation,
Diameter of camshaft = (0.16×Dbore) + 12.7
= (0.16 × 0.049) + 12.7 ×10-3
= 0.02054 m
= 0.02054 × 103 mm
= 20.54 mm (Approximately 21mm)

Base circle diameter:

Dbase circle = Dcamshaft+ 3mm
= 21+3
= 24 mm

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Width of cam:
(Wc) = (0.09 × Dbore) + 6 ×10-3
= (0.09 0.049) + 6 ×10-3
Wcam = 10.41mm

Forces:

Force (F) = Ffollower + Rrocker arm

Forces on inlet cam:

Frockerarm = Fs + Fa + Ff
Fs = π/4 d iv 2 × ps
Fs = spring force.
div = dip+ 2(0.05 dip to 0.07 dip)
= 0.0197 + 2(0.05 × 0.0197)
= 0.0220 m.
dv = Valve diameter.
Ps = maximum suction pressure < atmospheric pressure = 0.01N/mm2
Fs = π/4 (0.0220)2 × (0.01)
= 3.38013 × 10-6 N/mm2
Fva = mv × av.
mv = 8grms.
Speed of camshaft (N) = 8000/2
= 4000rpm.
In degrees per sec = 4000/60 × 360˚
= 2400˚/sec.
t = 58˚ /24000˚
= 2.4166×10-3 sec.

Acceleration:

hv = ut + ½ avt2 [u=0]
7.99 ×10-3 = (0) (2.4166 × 10-3) + 0.5×av× (2.4166 ×10-3)2
7.99×10-3 = 0 + 2.9210 ×10-6 av
av = (7.99 ×10-3)/(2.9201 × 10-6)
av = 2736.1712 m/s2
Fva = 8×2736.1712
Fva = 21.889 N
Fa = acceleration force.
Ff = Inertia force
= mf × af
=40×af
af = hf× 2/ a2×4
=2×π×N/60
=2×π×4000/60
=418.87rad/sec
a=58˚
=58×π/180
=1.0122rad
af = (7.99×10-3) × (418.87/1.0122)2×4
= (7.99×10-3) ×171248.1339×4
= 5473.090 m/sec2.
Ff = 40×af
= 40×5473.09
= 218923.6143
= 218.923 N.
Ft = Fs + Fa + Ff
= 3.8013 + 21.889 + 218.923
= 244.6133 N.

Force on Exhaust Cam:

Fe = Fs + Fa + Fg + Ff
Fs = π/4dev2 × Ps
dev = dep + 2 × (0.05 dep to 0.07 dep)
= 0.0187 + 2 * 0.06 *0.0187
= 0.0209 m.
Ps = 0.01 N/mm2
Fs = π/4 × (0.0209)2 ×0.01
= 3.4306 ×10-6
= 3.4306 N
Fa = mv ×av
mv = 8 gms
N = 8000/2
= 4000rpm
In degrees per second = 4000/60 ×360˚
= 24000˚/sec
t = 58/24000
= 2.4166 ×10-3 sec

Acceleration:

hv = ½ ×av ×t2
7.6114 ×10-3 = 0.5 ×av × (2.4166*10-3)
av = (7.6114×10-3)/(2.9201×10-6)
= 2606.5545m/sec2
Fa = mv ×av
= 8*2606.5545
= 20852.4365
= 20.8524 N.
Ff = mf ×af
mf = 40gms
af = hv × (2/ a2) ×4
= 7.6114 ×10-3 ×(418.887/1.0122)2 × 4
=5213.7521 m/sec2

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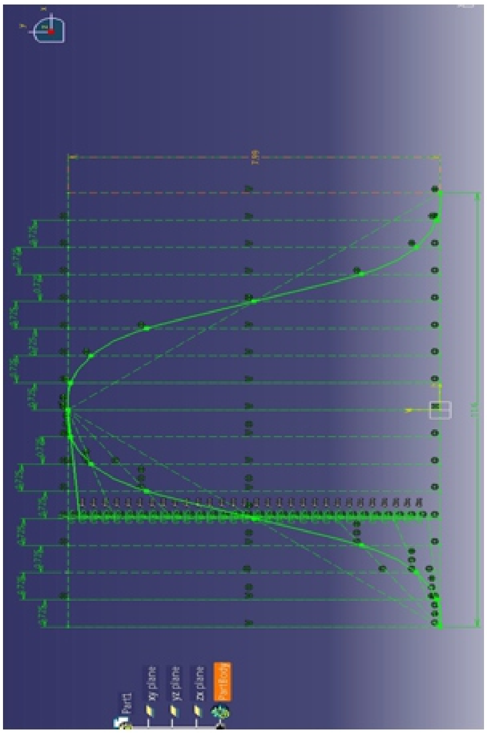
Ff = 40 × 5213.7521
= 208550.0874
= 208.5500874 N
Fg = π/4 ×dv2 ×Pmax
Pmax = 5.25 kw
I.P = PmLAN/60
5.25 ×103 = Pmax ×0.0521 ×π/4 × (0.049)2 ×4000/60
Pmax = 5.25 ×103/6.5372 ×10-3
=803091.7738 N/m2
Fg = π/4 ×dev2 ×Pmax
= π/4 × (0.0209)2 ×803.091
= 275.516 N
Fe = 3.4306 + 208.550 + 20.8524 + 275.516
=508.349 N.

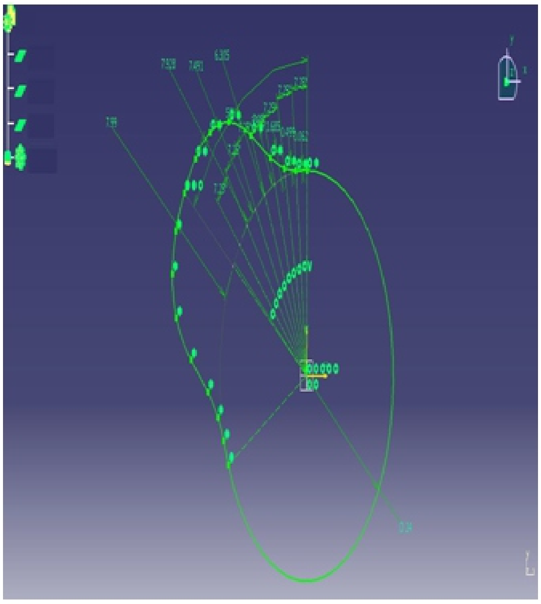
MODELLING AND DESIGN

Modeling of camshaft at Inlet:

1Inlet Cam Displacement Diagram:

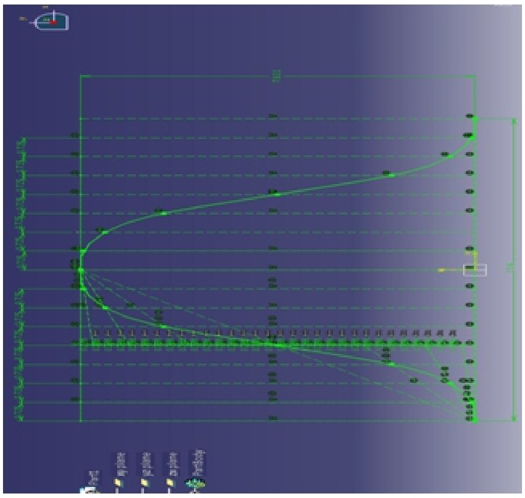


Inlet Cam Profile:

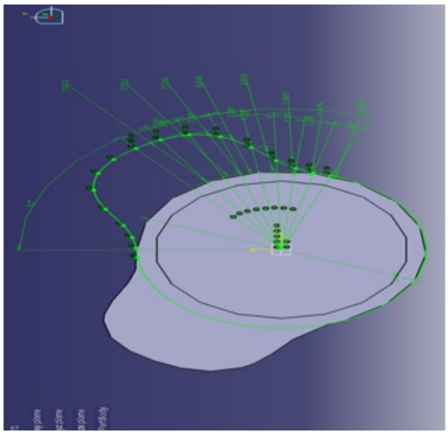


8.2 Modeling of camshaft at Outlet:

8.2.1 Exhaust Cam Displacement:



8.2.2 Outlet Cam Profile:



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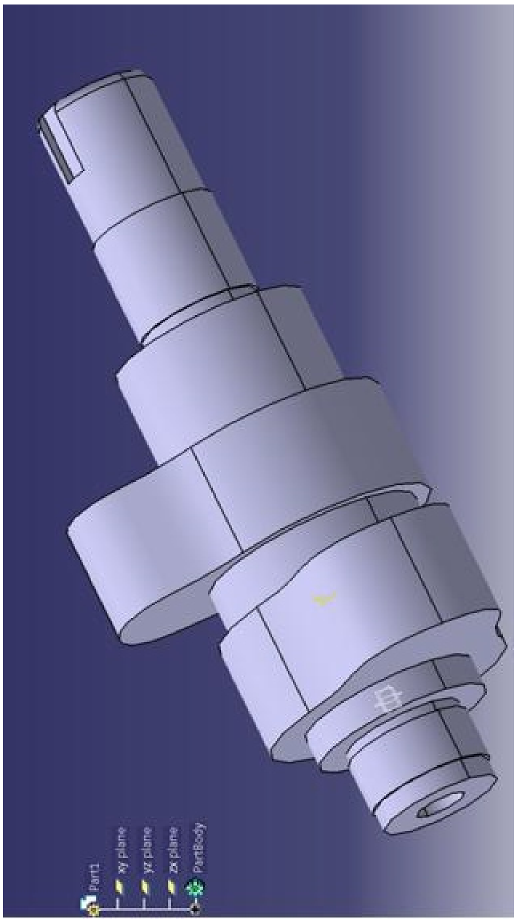
8.3 Final Model of Cam Shaft:



Views:

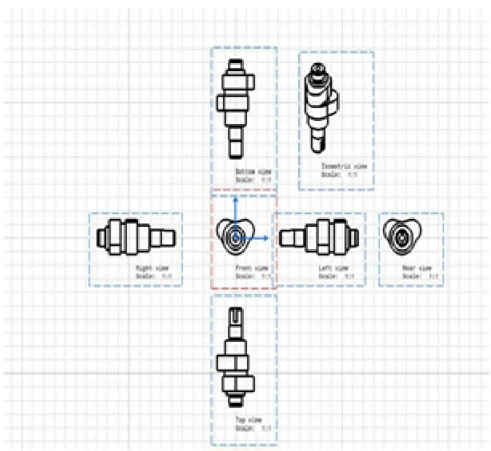
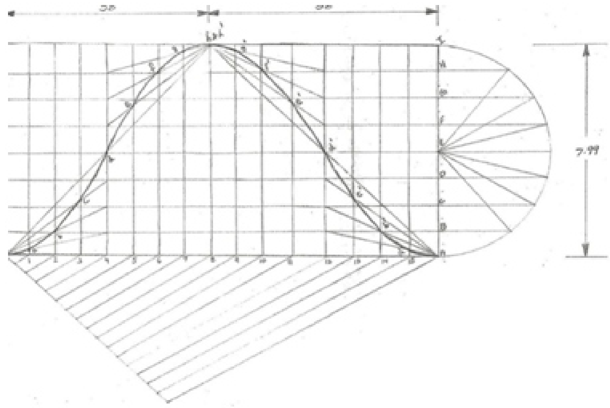


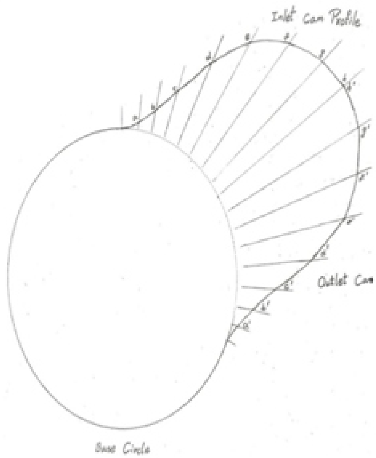
Fig 8.4 Views Of The Camshaft

Dimensioning:

Generate Dimensions, To generate dimensions in one shot from the constraints of a 3D part.

Only the following constraints can be generated: distance, length, angle, radius and diameter. Dimensions, To create and modify dimensions. These dimensions will be associative to the elements created from a part or an assembly. When created, these elements are associated with a view. Generate Balloons, to generate balloons automatically to the components of an assembly which are previously generated in assembly.





Profile of Cam

STRUCTURAL ANALYSIS OF CAST IRON
Structural Analysis Of Camshaft Using Cast Iron:
Imported model:

As the model is complex and non-linear, this structure is imported from 3D modeling software (CATIA).

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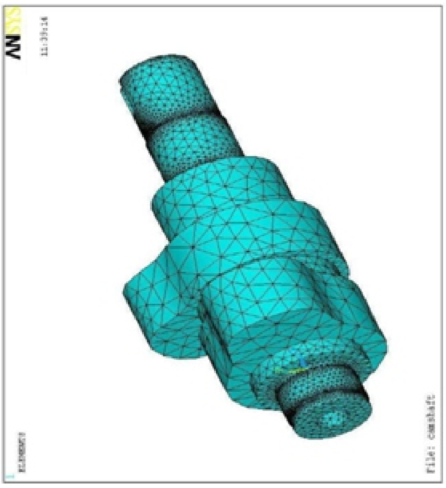
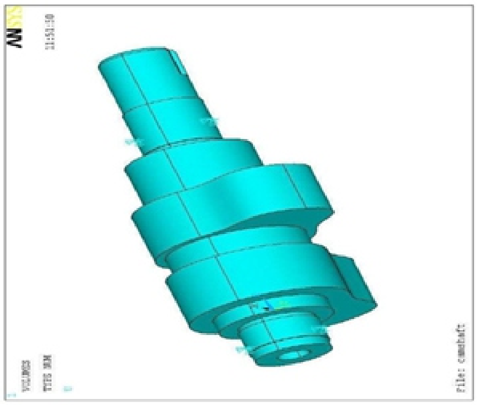
Element type:
Tetrahedral 10 node 187.
As the element is having a non-linear complex structure, this element is used to solve non- linearities in the structure.
Material Properties:
Material : cast iron.
Young's modulus: 1.4 Gpa
Poisson's ratio : 0.26
Density: 7300 Kg/m3
Meshing:
This solid model is meshed with smart size 6. Therefore the modeled structure has been divided into finite number of elements with an edge length of 6.
Meshed Model:

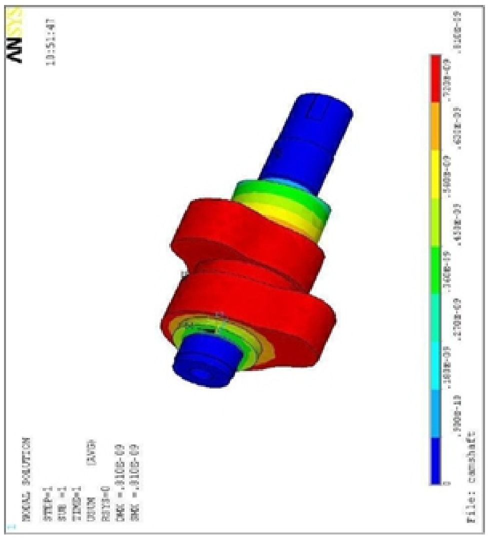


Loads:
Displacements (UX, UY, UZ, ROTX, ROTY, ROTZ)
These are DOF constraints usually specified at model boundaries to define rigid support points. They can also indicate symmetry boundary conditions and points of known motion. The directions implied by the labels are in the nodal coordinate system.



Forces (FX, FY, FZ):
These are concentrated loads usually specified on the model exterior. The directions implied by the labels are in the nodal coordinate system.
Forces applied on cams:
Force on inlet cam = 244.6133N (Fy direction)
Force on exhaust cam = 508.3499N (Fy direction)
Solve the analysis:
If you want the analysis to include additional loading conditions (that is, multiple load steps), you will need to repeat the process of applying loads, specifying load step options, saving, and solving for each load step and Leave solution.
Results:
Results can be viewed from general postprocessor. In this postprocessor, results like deformed shape, displacement diagram and vonmisses stress in the structure etc..,

Displacement vector sum:



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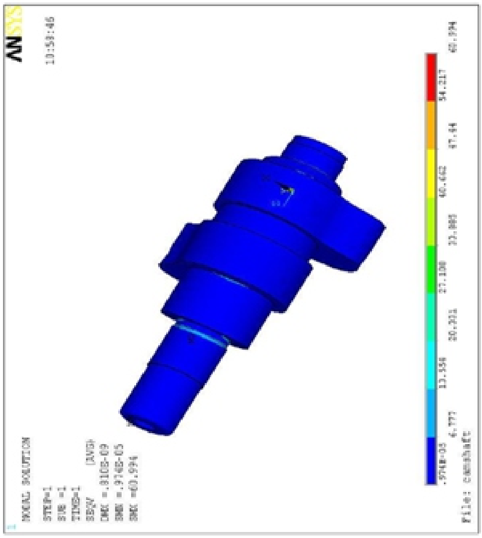
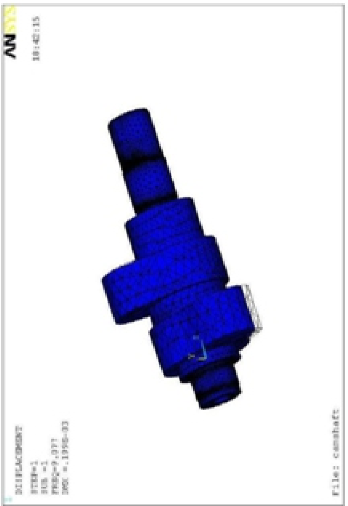
Von Mises stress:

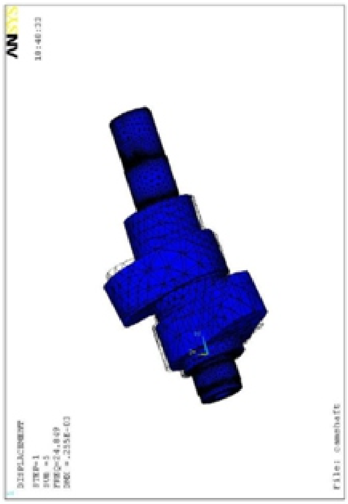


10.2. Model Analysis Of Cam Shaft Using Cast Iron:

In this step we define the analysis type and options, apply loads, specify load step options, and begin the finite element solution for the natural frequencies

Results:





NICKEL-CHROMIUM-MOLYBDEUM STEEL

Structural Analysis Of Cam Shaft Using Nickel-Chromium-Molybdenum Steel

Element type:

Tetrahedral 10 node 187
As the element is having a non-linear complex structure, this element is used to solve non- linearities in the structure.
Material Properties:
Material: Nickel Chromium Molybdenum Steel
Young's modulus: 2.07Gpa
Poisson's ratio : 0.291
Density : 7800 Kg/m3
Meshing:
This solid model is meshed with smart size 6. Therefore the modeled structure has been divided into finite number of elements with an edge length of 6.
Forces (FX, FY, FZ):
These are concentrated loads usually specified on the model exterior. The directions implied by the labels are in the nodal coordinate system.
Forces applied on cams:
Force on inlet cam = 244.6133N
Force on exhaust cam = 508.3499N
Solve the analysis:
If you want the analysis to include additional loading conditions (that is, multiple load steps), you will need to repeat the process of applying loads, specifying load step options, saving, and solving for each load step and Leave solution.

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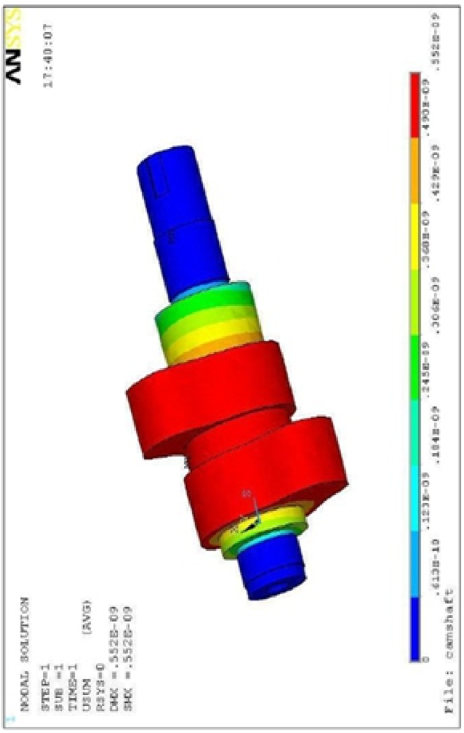
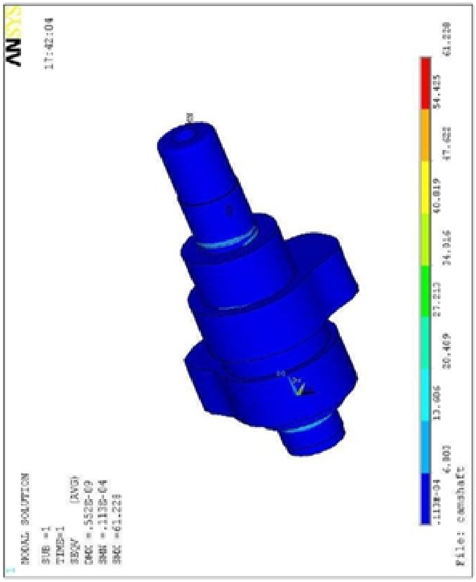
Results:
Results can be viewed from general postprocessor. In this postprocessor, results like deformed shape, displacement diagram and von misses stress in the structure etc..,

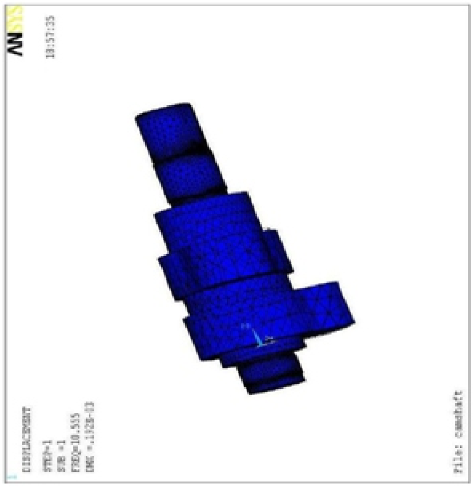
Displacement Vector Sum:

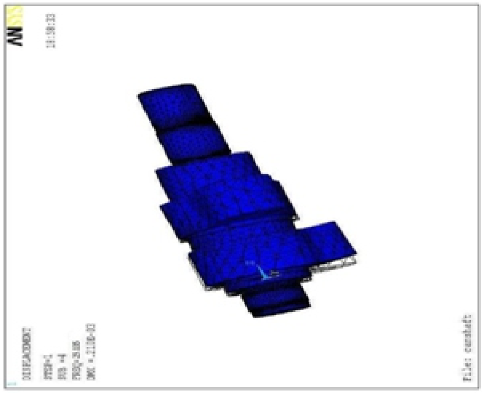


Von mises Stress:



11.2 Modal Analysis Of Cam Shaft Using Nickel-Chromium-Molybdenum Steel: RESULTS:





RESULT AND DISCUSSION:

On performing structural analysis and modal analysis of camshaft using both the materials, the following results were obtained.

•From structural analysis, the displacement and stress values of camshaft using cast iron an nickel chromium molybdenum steel are as follows:

	Displacement (m)	Stress (Mpa)
Cast iron	.810e-9	60.994
Nickel chromium molybdenum steel	.552e-9	61.228

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•From the above table, it is clear that camshaft displaces less in case of nickel chromium steel when compared to cast iron.
•From modal analysis, the modal frequency of camshaft using cast iron and nickel chromium molybdenum steel are as follows:

Frequency	Cast Iron	Nickel Chromium Molybdenum Steel
1	9.0775	10.555
2	12.459	14.606
3	12.825	15.045
4	22.172	26.229
5	24.849	29.139

•From the above table, as the modal frequencies for camshaft using nickel chromium molybdenum steel is more compared to cast iron.

	Cast Iron	Nickel Chromium Molybdenum Steel
Factor of Safety	3.738	11.432

•On comparing all the above results, camshaft made of nickel chromium molybdenum steel is preferred.

CONCLUSION:

In this project Design and Model Analysis of camshaft is done by using CATIA and ANSYS software. By using ANSYS the model analysis is done to find out the natural frequencies of Cam. The displacement and stress are calculated.The design of the cam is done by using CATIA software. The design is done by using cam profile at inlet and outlet (exhaust). The Cam have knife edge follower.

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